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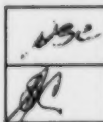
### EXECUTIVE SUMMARY

#### STEAM-WATER IODINE PARTITIONING EXPERIMENT PHASE 1

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Fission products may be released into containment in the event of a Loss of Coolant Accident (LOCA). When pressurized heavy water escapes from the primary system, it will flash into steam and water drops. It is necessary to know the extent to which fission products will partition between the liquid and gaseous phases. This will assist in the prediction of fission product transport in containment and possible releases to the environment. The focus of the Steam-Water Iodine Partitioning Experiment (SWIPE) is to measure the partitioning of iodine in a flashing steam-water jet.

The first phase of the project is complete. It includes the installation and commissioning of the facility (described in report 87-320-K) and the parametric evaluation of iodine partitioning. The effect of various chemical and thermal initial conditions on the iodine partitioning coefficient was studied. This report describes the operating procedure, the method of data reduction and the results. Modifications in the operating procedure are recommended for future tests.



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To Dr. R.A. Brown  
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STEAM-WATER IODINE PARTITIONING EXPERIMENT  
PHASE 1

1.0 INTRODUCTION

It is important to assess the potential for release of fission products to the environment in the event of a Loss of Coolant Accident. Some amount of fission product escapes from the fuel and enters the coolant. In the event of a LOCA, coolant escapes into containment as a flashing jet. During the flashing process, some fission products will partition into the steam phase. In the containment system, there are many pathways for fission product transport and depletion. The fission products may escape to the environment through cracks in containment or through the filtering system. The purpose of this study, named the Steam-Water Iodine Partitioning Experiment (SWIPE), was to measure the partitioning of iodine in a flashing steam-water jet.

Iodine was chosen as a representative fission product because airborne iodine released to the environment is a safety hazard to human health. Iodine can be released from the fuel in many forms. One of these is Cesium Iodide; and this chemical form will be studied in the present experiment. This compound has two important characteristics: 1. the Iodine is present in the form of a negative ion and 2. the Cesium, which is non-volatile, will act as a tracer for non-flashed liquid.

The description of the facility and the commissioning process are described in report 87-320-K. This report describes the operating procedure and results of the chemical analysis.

## 2.0 PHASE 1 - PARAMETRIC EVALUATION

The purpose of this phase was to evaluate the effect of various chemical and thermal initial conditions on the partitioning coefficient.

### 2.1 OPERATING PROCEDURE

The following operating procedure was used for tests IPEX 10-16:

1. Deionized water from Chemical Research with a conductivity of 1-2  $\mu$  mho/cm was collected on the same day as the test.
2. Standard concentrations of Cesium Iodide and the other chemicals added to the deionized water were prepared by the Chemical Analysis Section.
3. Each beaker and graduated cylinder was cleaned with deionized water before each test and was used with only one chemical solution and with only one concentration. Each piece of glassware was labelled for its specific function. New clean plastic sample bottles were labelled with black felt pen. The labelling symbols were as follows: B-boiler, S-separator, C-condenser, Cs-cesium, I-iodine, R-resin concentration.
4. A concentrated solution of chemical was poured into the plastic container of deionized water. This diluted solution was then pumped into the pressure vessel. The vent line was allowed to overflow into the filling container and the filling pump was run for a few more minutes to encourage thorough mixing of the chemical.
5. After filling, two samples, each with a volume of 100 ml, were taken from the pressure vessel. These samples were measured for pH and conductivity.

6. The heater was turned on by setting the temperature controller to the desired setpoint and resetting the temperature overload relay. The vent line was kept open until a few minutes after boiling started to drive out air in the pressure vessel.
7. While heatup was in progress, the data acquisition computer was started to monitor the vessel pressure and temperature.
8. When heatup was finished, the temperature override switch was set to 0°C to ensure the heaters remained off during the blowdown.
9. The data acquisition computer was set up to log temperatures and pressures and data collection was initiated. Then the valve between the pressure vessel and nozzle was opened to initiate the blowdown.
10. After 500 ml of condensate had passed through the condenser, sampling began. Two samples each from the separator and the condenser were taken during the blowdown. 100 ml samples were taken from the separator and 250 ml samples were taken from the condenser. The blowdown continued until the condenser samples were collected which was approximately 5 minutes.
11. A portion of the sampled liquid was put into the iodine sample bottles and sent the same day to the radiation lab. At that lab, the samples were transferred into sealed vials for NAA analysis. If the initial concentration of iodine was 1 ppm or less then concentrated samples were prepared in the Thermo-Fluids lab. To do so, 100 ml of sample liquid was passed through 0.5 ml of mixed bed resin. This operation required approximately 6 hours. The resin was then taken to the radiation lab for NAA analysis.

12. The remaining liquid in the sample beakers was acidified to pH 2 using nitric acid and was then put into the sample bottles. These samples were taken to the Chemical Analysis Section for Cesium analysis.

## 2.2 MODIFICATIONS TO PROCEDURE FOR IPEX SERIES 20

5. Boiler samples were not taken after filling the pressure vessel.
- 8a. After heatup was finished, two 100 ml samples were taken from the pressure vessel using the drainage port and the cooling tube. These samples were labelled B1 and B2.
- 10a. After the blowdown was completed, two additional samples were taken from the pressure vessel in the same manner. These samples were labelled B3 and B4.

### 2.3 DATA REDUCTION & RESULTS

The partitioning coefficient,  $R_p$ , was defined as follows:

$$R_p = \frac{(Cs/I)_{\text{condenser}}}{(Cs/I)_{\text{separator}}}$$

where Cs = the concentration of Cesium

I = the concentration of Iodine

An error estimate of this coefficient was based on first order differentials.

$$\Delta R_p \approx \left[ \frac{\partial R_p}{\partial Cs_c} \Delta Cs_c + \frac{\partial R_p}{\partial I_c} \Delta I_c + \frac{\partial R_p}{\partial Cs_s} \Delta Cs_s + \frac{\partial R_p}{\partial I_s} \Delta I_s \right]$$

where  $\Delta Cs$  = measurement error for Cesium  
 =  $\pm 0.020$  ppm for AAS flame test  
 =  $\pm 0.002$  ppm for FAAS flameless test  
 $\Delta I$  = measurement error for Iodine  
 =  $\pm 0.040$  ppm for NAA 10ml sample 20kW 6min  
 =  $\pm 0.005$  ppm for NAA with pre-concentrated samples

The subscripts 's' and 'c' represent separator and condenser samples respectively. Unless otherwise specified, AAS was used for Cesium analysis and NAA with 10ml samples was used for Iodine analysis. The measurement error for each analysis technique is shown above.

The initial test matrix included 5 parameters which could possibly affect the partitioning coefficient. These were the reservoir temperature, pH, initial concentration of Cesium & Iodine and air entrainment vs no air entrainment. For the first series of tests, series 10, the parameters were temperature, pH and initial concentration with air entrainment. Series 20 included a repeat of some series 10 tests with no air entrainment. Table 1 shows the

results of these tests. The iodine partitioning coefficients are shown in Table 2.

IPEX 10 and 11 were run at the same conditions and the results were similar,  $R_p = 1.1$ . For the case of high pH (IPEX 13) and large subcooling (IPEX 12),  $R_p$  was less than one. To quantify the iodine partitioning, the concentration of iodine in the vapour phase was estimated. This calculation assumed that cesium existed only in the liquid phase, cesium was carried over to the condenser in aerosols and the concentration of cesium in the aerosols equalled the concentration of cesium in the separator. Performing a mass balance for cesium in the condenser, the mass of aerosols carried over to the condenser,  $M_a$ , was estimated from:

$$Cs_c M_c = Cs_s M_a + 0 \cdot M_v$$

To perform a mass balance for iodine in the condenser, it was assumed that the concentration of iodine in the aerosols was equal to the concentration of iodine in the separator. A mass balance for iodine was combined with the above equation to give the estimate of iodine in the vapour phase,  $I_v$ :

$$I_v = \frac{(I_c/I_s) - (Cs_c/Cs_s)}{(1 - Cs_c/Cs_s)}$$

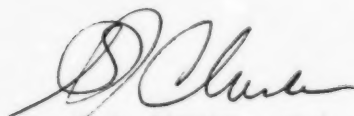
The results of the mass balance are shown in Table 3. Three of the tests in series 10, yielded negative values for  $I_v$ . Since this is not physically possible in a closed system, some Cesium or Iodine was unaccounted for. Possible reasons for this are plateout in the boiler and glassware or leakage from the separation equipment. To better account for the Cesium and Iodine, a mass balance on Cesium, Iodine and water was required. This was performed in Series 20. IPEX 20 showed a good balance with Cs and I. However, the purge showed large amounts of Cs and Iodine were left in the boiler. There were large errors in Cs mass balance for IPEX 22 & 23. These cases were run without a prior purge.

### 3.0 CONCLUSIONS

The previous test series showed that changes in the order of tests and purging before a test could affect the Cesium and Iodine concentrations. For subsequent tests, the following modifications to the operating procedure are recommended:

1. Before filling the boiler with Cesium-Iodide solution, fill the boiler with deionized water and drain it.
2. Follow the procedure for a blowdown using deionized water to fill the boiler. This is a purge.
3. After the purge dry the separation equipment by blowing hot air into the separator. Let it run overnight.
4. During blowdown, sample each minute upstream from the discharge valve.

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Table 1 - SWIPE PHASE 1 TEST RESULTS

| FILE   | Press<br>[MPa] | Temp<br>[°C] | pH    | Cs <sub>bi</sub><br>[ppm] | Cs <sub>bf</sub><br>[ppm] | I <sub>bi</sub><br>[ppm] | I <sub>bf</sub><br>[ppm] | Cs <sub>s</sub><br>[ppm] | I <sub>s</sub><br>[ppm] | Cs <sub>c</sub><br>[ppm] | I <sub>c</sub><br>[ppm] |
|--------|----------------|--------------|-------|---------------------------|---------------------------|--------------------------|--------------------------|--------------------------|-------------------------|--------------------------|-------------------------|
| IPEX10 | 3.0            | 234          | 6.00  | 86                        | —                         | 80                       | —                        | 123                      | 113                     | 1.19                     | 1.00                    |
| IPEX11 | 3.0            | 234          | 6.10  | 81                        | —                         | 78                       | —                        | 136                      | 123                     | 1.25                     | 1.00                    |
| IPEX12 | 3.0            | 147          | 6.00  | 84                        | —                         | 76                       | —                        | 105                      | 98                      | 0.43                     | 0.50                    |
| IPEX13 | 3.0            | 234          | 10.80 | 87                        | —                         | 73                       | —                        | 125                      | 106                     | 0.92                     | 0.87                    |
| IPEX14 | 3.0            | 234          | 6.25  | 1351                      | 1427                      | 75.8                     | 78.5                     | 1955                     | 108                     | 16.6                     | 0.95                    |
| IPEX15 | 3.0            | 234          | 7.00  | 16.5                      | 20.0                      | 246                      | 235                      | 17.3                     | 320                     | 0.23                     | 1.40                    |
| IPEX16 | 3.0            | 234          | 10.25 | 1.02                      | 1.42                      | 0.82                     | 0.97                     | 1.39                     | 1.16                    | 0.02                     | 0.02                    |
| IPEX20 | 3.0            | 234          | 6.75  | 91                        | 92                        | 81                       | 81                       | 126                      | 114                     | 0.42                     | 0.39                    |
| PURGE1 | 3.0            | 234          |       |                           | 36                        |                          | 35                       |                          |                         | <0.05                    | <0.02                   |
| IPEX21 | 3.0            | 234          | 6.75  | 8.7                       | 9.4                       | 78                       | 84                       | 12.8                     | 116                     | 0.06                     | 0.46                    |
| IPEX22 | 3.0            | 234          | 6.75  | 913                       | 957                       | 84                       | 83                       | 1357                     | 113                     | 4.40                     | 0.58                    |
| IPEX23 | 3.0            | 234          | 6.20  | 16                        | 16.2                      | 85                       | 86                       | 16.4                     | 112                     | 0.44                     | 0.45                    |
| PURGE2 | 3.0            | 234          |       | 0.84                      | 0.67                      | 2.4                      | 1.5                      | 1.03                     | 2.0                     | 0.21                     | 0.03                    |

Table 2 - IODINE PARTITIONING COEFFICIENT

| FILE   | Rp  | error  | Ma/Mc  | Iv<br>[ppm] | Iv/Is  | error   |
|--------|-----|--------|--------|-------------|--------|---------|
| IPEX10 | 1.1 | ±0.063 | 0.0097 | -0.094      | -0.001 | ±0.0006 |
| IPEX11 | 1.1 | ±0.064 | 0.0092 | -0.131      | -0.001 | ±0.0006 |
| IPEX12 | 0.8 | ±0.102 | 0.0041 | 0.099       | 0.001  | ±0.0007 |
| IPEX13 | 0.9 | ±0.061 | 0.0074 | 0.091       | 0.001  | ±0.0007 |
| IPEX14 | 1.0 | ±0.042 | 0.0085 | 0.0332      | 0.000  | ±0.0003 |
| IPEX15 | 3.0 | ±0.355 | 0.0133 | -2.892      | -0.009 | ±0.0024 |
| IPEX16 | 0.8 | ±0.322 | 0.0144 | 0.0033      | 0.003  | ±0.0073 |
| IPEX20 | 1.0 | ±0.147 | 0.0033 | 0.0100      | 0.000  | ±0.0006 |
| IPEX21 | 1.2 | ±0.499 | 0.0047 | -0.084      | -0.001 | ±0.0034 |
| IPEX22 | 0.6 | ±0.047 | 0.0032 | 0.2142      | 0.002  | ±0.0003 |
| IPEX23 | 6.7 | ±0.908 | 0.0268 | -2.625      | -0.023 | ±0.0029 |

Table 3 - Mass Balance

| FILE   | BOILER        |            |           | SEPARATOR     |            |           | CONDENSER     |            |           | MASS BALANCE            |       |       |
|--------|---------------|------------|-----------|---------------|------------|-----------|---------------|------------|-----------|-------------------------|-------|-------|
|        | Water<br>[kg] | Cs<br>[gm] | I<br>[gm] | Water<br>[kg] | Cs<br>[gm] | I<br>[gm] | Water<br>[kg] | Cs<br>[gm] | I<br>[gm] | Water<br>[% discharged] | Cs    | I     |
| IPEX20 | 14.1          | 1.29       | 1.14      | 10.1          | 1.27       | 1.15      | 3.50          | 0.0014     | 0.0013    | 3.5%                    | 1.2%  | -0.9% |
| IPEX21 | 14.5          | 0.13       | 1.17      | 9.88          | 0.13       | 1.15      | 3.55          | 0.0002     | 0.0016    | 7.4%                    | 3.5%  | 2.3%  |
| IPEX22 | 14.8          | 13.8       | 1.24      | 10.9          | 14.8       | 1.23      | 3.74          | 0.0164     | 0.0021    | 1.1%                    | -7.0% | 0.2%  |
| IPEX23 | 13.8          | 0.22       | 1.18      | 10.2          | 0.17       | 1.14      | 3.60          | 0.0015     | 0.0016    | 0.0%                    | 24.0% | 3.0%  |